

WHAT IS CLAIMED IS:

[c01] A phosphor comprising a material having a formula of  $AMgD_{10}O_{17}:Eu^{2+},Mn^{2+}$ , wherein A is at least an alkaline-earth metal selected from the group consisting of Ba, Sr, Ca, and combinations thereof; and D is at least a metal selected from the group consisting of Al, Ga, In, and combinations thereof; wherein  $Eu^{2+}$  ions are present in an amount from about 10 to about 50 atom percent of a combined quantity of A ions and europium ions, and  $Mn^{2+}$  ions are present in an amount from about 5 to about 30 atom percent of a combined quantity of magnesium ions and manganese ions.

[c02] A phosphor comprising a material having a formula of  $AMgD_{10}O_{17}:Eu^{2+},Mn^{2+}$ , wherein A is at least an alkaline-earth metal selected from the group consisting of Sr, Ca, and combinations thereof; and D is at least a metal selected from the group consisting of Al, Ga, In, and combinations thereof; wherein  $Eu^{2+}$  ions are present in an amount from about 10 to about 40 atom percent of a combined quantity of A ions and europium ions, and  $Mn^{2+}$  ions are present in an amount from about 5 to about 20 atom percent of a combined quantity of magnesium ions and manganese ions.

[c03] The phosphor according to claim 1, wherein  $Eu^{2+}$  ions are present in an amount from about 20 to about 40 atom percent of a combined quantity of A ions and europium ions, and  $Mn^{2+}$  ions are present in an amount from about 10 to about 20 atom percent of a combined quantity of magnesium ions and manganese ions.

[c04] The phosphor according to claim 1, wherein D is at least a metal selected from the group consisting of Ga, In, and combinations thereof.

[c05] The phosphor according to claim 1, wherein a portion of magnesium ions is substituted with Zn in an amount from about 0.01 to about 99.99 atom percent of a combined quantity of Mg, Mn, and Zn ions.

[c06] A method for producing a phosphor, the method comprising:

providing amounts of oxygen-containing compounds of magnesium; europium; manganese; at least another alkaline-earth metal, which is selected from the group consisting of barium, strontium, calcium, and combinations thereof; and at least a metal of Group III-B of the Periodic Table of the Elements, the metal of Group-III B being selected from the group consisting of Al, Ga, In, and combinations thereof;

mixing together the oxygen-containing compounds to form a mixture;

and

firing the mixture at a temperature between about 1000 C and about 1600 C under a reducing atmosphere for a sufficient period of time to convert the mixture to said phosphor having a formula of  $(A_{1-a}Eu_a)(Mg_{1-b}Mn_b)D_{10}O_{17}$ ; wherein A is said at least another alkaline-earth metal, D is said at least a metal of Group-III B,  $0.001 < a \leq 0.5$ , and  $0.001 < b \leq 0.3$ .

[c07] The method according to claim 6, wherein the reducing atmosphere is selected from the group consisting of hydrogen, carbon monoxide, ammonia, and mixtures thereof with an inert gas selected from the group consisting of nitrogen, helium, neon, argon, krypton, and xenon.

[c08] The method according to claim 6, wherein the reducing atmosphere is selected from the group consisting of a product of incomplete combustion carbon in air, and decomposition products of compounds that give at least one gas selected from the group consisting of hydrogen and carbon monoxide.

[c09] The method according to claim 6, wherein the reducing atmosphere is selected from the group consisting of decomposition products of ammonia and hydrazine.

[c10] The method according to claim 6, wherein the firing temperature is in a range from about 1400 C to about 1600 C.

[c11] The method according to claim 6, wherein the firing time is in a range from about 1 minute to 10 hours.

[c12] The method according to claim 6, wherein the oxygen-containing compounds are selected from the group consisting of oxides, carbonates, nitrates, sulfates, phosphates, citrates, carboxylates, and combinations thereof.

[c13] The method according to claim 6, further comprising adding a flux to the oxygen-containing compounds before the step of mixing, wherein the flux comprises a fluoride of at least an element selected from the group consisting of Mg, Eu, Mn, said at least an alkaline-earth metal, and said at least a Group-III B metal.

[c14] A method for producing a phosphor, the method comprising:  
providing a first solution that comprises compounds of magnesium; europium; manganese; at least another alkaline-earth metal, which is selected from the group consisting of barium, strontium, and calcium; and at least a Group-III B metal selected from the group consisting of Al, Ga, In, and combinations thereof;

providing a second solution, which comprises at least a compound that is capable of producing a precipitate when the first and second solutions are mixed together;

mixing the first and second solutions to produce a precipitate containing magnesium, europium, manganese, said at least another alkaline-earth metal, and said at least a Group-III B metal; and

firing the mixture under a reducing atmosphere at a temperature and for a sufficient period of time to convert the mixture to a phosphor having a formula of  $(A_{1-a}Eu_a)(Mg_{1-b}Mn_b)D_{10}O_{17}$ ; wherein A is said at least another alkaline-earth metal; D is said at least a Group-III B metal;  $0.001 < a \leq 0.5$ ; and  $0.001 < b \leq 0.3$ .

[c15] The method according to claim 14, wherein the second solution comprises a compound selected from the group consisting of ammonium hydroxide;

and hydroxides of at least one element selected from the group consisting of magnesium, europium, manganese, said at least another alkaline-earth metal, and said at least a Group-IIIB metal.

[c16] The method according to claim 14, wherein the second solution comprises a compound selected from the group consisting of organic esters of carboxylic acids, organic amines, and combinations thereof.

[c17] The method according to claim 14, wherein the reducing atmosphere is selected from the group consisting of hydrogen, carbon monoxide, ammonia, and mixtures thereof with an inert gas selected from the group consisting of nitrogen, helium, neon, argon, krypton, and xenon.

[c18] The method according to claim 14, wherein the reducing atmosphere is selected from the group consisting of a product of a incomplete combustion carbon in air, and decomposition products of compounds that give at least one gas selected from the group consisting of hydrogen and carbon monoxide.

[c19] The method according to claim 14, wherein the reducing atmosphere is selected from the group consisting of decomposition products of ammonia and hydrazine.

[c20] The method according to claim 14, wherein the firing temperature is in a range from about 1400 C to about 1600 C.

[c21] The method according to claim 14, wherein the firing time is in a range from about 1 minute to 10 hours.

[c22] A phosphor blend comprising:

a phosphor comprising a material having a formula of  $AMgD_{10}O_{17}:Eu^{2+},Mn^{2+}$ , wherein A is at least an alkaline-earth metal selected from the group consisting of Ba, Sr, Ca, and combinations thereof; and D is at least a metal selected from the group consisting of Al, Ga, In, and combinations thereof; wherein

$\text{Eu}^{2+}$  ions are present in an amount from about 10 to about 50 atom percent of a combined quantity of A ions and europium ions, and  $\text{Mn}^{2+}$  ions are present in an amount from about 5 to about 30 atom percent of a combined quantity of magnesium ions and manganese ions; and

at least another phosphor emitting a light color selected from the group consisting of blue, blue-green, green, yellow, yellow-orange, orange-red, and red.

[c23] The phosphor blend according to claim 22, wherein said at least another phosphor is selected from the group consisting of  
 $(\text{Ba},\text{Sr},\text{Ca})_5(\text{PO}_4)_3(\text{Cl},\text{F},\text{OH})\text{:Eu}^{2+}$ ;  $(\text{Ba},\text{Sr},\text{Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}$ ;  $(\text{Ba},\text{Sr},\text{Ca})\text{BPO}_5\text{:Eu}^{2+}$ ;  
 $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$ ;  $\text{BaAl}_8\text{O}_{13}\text{:Eu}^{2+}$ ;  $2\text{SrO}\bullet 0.84\text{P}_2\text{O}_5\bullet 0.16\text{B}_2\text{O}_3\text{:Eu}^{2+}$ ;  $\text{MgWO}_4$ ;  $\text{BaTiP}_2\text{O}_8$ ;  
 $(\text{Ba},\text{Sr},\text{Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+},\text{Mn}^{2+}$ ;  $(\text{Ba},\text{Sr},\text{Ca})_5(\text{PO}_4)_3(\text{Cl},\text{F},\text{OH})\text{:Sb}^{3+}$ ;  
 $\text{LaPO}_4\text{:Ce}^{3+},\text{Tb}^{3+}$ ;  $\text{CeMgAl}_{11}\text{O}_{19}\text{:Tb}^{3+}$ ;  $\text{GdMgB}_5\text{O}_{10}\text{:Ce}^{3+},\text{Tb}^{3+},\text{Mn}^{2+}$ ;  
 $\text{GdMgB}_5\text{O}_{10}\text{:Ce}^{3+},\text{Tb}^{3+}$ ;  $(\text{Tb},\text{Y},\text{Lu},\text{La},\text{Gd})_3(\text{Al},\text{Ga})_5\text{O}_{12}\text{:Ce}^{3+}$ ;  
 $(\text{Ba},\text{Sr},\text{Ca})_5(\text{PO}_4)_3(\text{Cl},\text{F},\text{OH})\text{:Eu}^{2+},\text{Mn}^{2+},\text{Sb}^{3+}$ ;  $(\text{Y},\text{Gd},\text{La},\text{Lu},\text{Sc})_2\text{O}_3\text{:Eu}^{3+}$ ;  
 $(\text{Y},\text{Gd},\text{La},\text{In},\text{Lu},\text{Sc})\text{BO}_3\text{:Eu}^{3+}$ ;  $(\text{Y},\text{Gd},\text{La})(\text{Al},\text{Ga})\text{O}_3\text{:Eu}^{3+}$ ;  
 $(\text{Ba},\text{Sr},\text{Ca})(\text{Y},\text{Gd},\text{La},\text{Lu})_2\text{O}_4\text{:Eu}^{3+}$ ;  $(\text{Y},\text{Gd})\text{Al}_3\text{B}_4\text{O}_{12}\text{:Eu}^{3+}$ ; monoclinic  $\text{Gd}_2\text{O}_3\text{:Eu}^{3+}$ ;  
 $(\text{Gd},\text{Y})_4(\text{Al},\text{Ga})_2\text{O}_9\text{:Eu}^{3+}$ ;  $(\text{Ca},\text{Sr})(\text{Gd},\text{Y})_3(\text{Ge},\text{Si})\text{Al}_3\text{O}_9\text{:Eu}^{3+}$ ;  $(\text{Sr},\text{Mg})_3(\text{PO}_4)_2\text{:Sn}^{2+}$ ;  
 $\text{GdMgB}_5\text{O}_{10}\text{:Ce}^{3+},\text{Mn}^{2+}$ ;  $3.5\text{MgO}-0.5\text{MgF}_2-\text{GeO}_2\text{:Mn}^{4+}$ .

[c24] The phosphor blend according to claim 22, wherein said at least another phosphor is selected from the group consisting of  
 $(\text{Sr},\text{Ca},\text{Mg},\text{Zn})_2\text{P}_2\text{O}_7\text{:Eu}^{2+},\text{Mn}^{2+}$ ;  $(\text{Sr},\text{Ba},\text{Ca})_5(\text{PO}_4)_3(\text{Cl},\text{F},\text{OH})\text{:Eu}^{2+}$ ; and  
 $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$ .

A light source emitting visible light, the light source comprising:

a radiation source that emits in a wavelength range from about 250 nm to about 480 nm; and

a phosphor having a formula of  $(\text{A}_{1-a}\text{Eu}_a)(\text{Mg}_{1-b}\text{Mn}_b)\text{D}_{10}\text{O}_{17}$ ; wherein A is at least an alkaline-earth metal other than Mg, D is at least a Group-IIIb metal;

$0.001 < a \leq 0.5$ , and  $0.001 < b \leq 0.3$ , which phosphor is disposed adjacent to the radiation source to receive the radiation and emit the visible light.

The light source according to claim 24, wherein the radiation source comprises a UV/blue light emitting diode ("LED").

[c25] The light source according to claim 25, wherein the phosphor is dispersed in a transparent casting, which disposed adjacent to the radiation source.

[c26] The light source according to claim 25, wherein the radiation source emits radiation having wavelengths in a range from about 250 nm to about 420 nm.

[c27] The light source according to claim 25, wherein the phosphor is a component of a phosphor blend that comprises at least one other phosphor emitting light selected from the group consisting of blue, blue-green, green, yellow, yellow-orange, orange-red, and red light.

[c28] The light source according to claim 26, further comprising particles of a scattering material dispersed in the transparent casting.

[c29] The light source according to claim 24, wherein the radiation source is a gas discharge device.

[c30] The light source according to claim 24, wherein the gas discharge device is selected from the group consisting of low-, medium-, and high-pressure mercury gas discharge lamps.

[c31] The light source according to claim 31, wherein the phosphor is a component of a phosphor blend that comprises at least one other phosphor emitting light selected from the group consisting of blue, blue-green, green, yellow, yellow-orange, orange-red, and red light.

[c32] The light source according to claim 24, wherein the radiation source is a cathode-ray tube.